



# **Runtime randomization and perturbation for virtual machines.**

JAVIER CABRERA ARTEAGA

Licentiate Thesis in [Research Subject - as it is in your ISP]  
School of Information and Communication Technology  
KTH Royal Institute of Technology  
Stockholm, Sweden [2022]

TRITA-ICT XXXX:XX  
ISBN XXX-XX-XXXX-XXX-X

KTH School of Information and  
Communication Technology  
SE-164 40 Kista  
SWEDEN

Akademisk avhandling som med tillstånd av Kungl Tekniska högskolan framlägg-  
ges till offentlig granskning för avläggande av licentiatexamen i [ämne/subject]  
[veckodag/weekday] den [dag/day] [månad/month] [år/2022] klockan [tid/time] i  
[sal/hall], Electrum, Kungl Tekniska högskolan, Kistagången 16, Kista.

© Javier Cabrera Arteaga, [month] [2022]

Tryck: Universitetsservice US AB

## Abstract

Write your abstract here...

**Keywords:** Keyword1, keyword2, ...

### **Sammanfattning**

Write your Swedish summary (popular description) here...

**Keywords:** Keyword1, keyword2, ...

## Acknowledgements

Write your professional acknowledgements here...

Acknowledgements are used to thank all persons who have helped in carrying out the research and to the research organizations/institutions and/or companies for funding the research.

*Name Surname,*  
Place, Date

# Contents

<b>Contents</b>	<b>vi</b>
<b>List of Figures</b>	<b>viii</b>
<b>List of Tables</b>	<b>ix</b>
<b>List of Acronyms</b>	<b>xi</b>
<b>1 Introduction</b>	<b>1</b>
1.1 Motivation . . . . .	1
1.1.1 Why variants ? . . . . .	1
1.1.2 Research questions . . . . .	1
1.2 Contributions . . . . .	1
<b>2 Background and State of the art</b>	<b>3</b>
2.1 CROW . . . . .	3
<b>3 Methodology</b>	<b>5</b>
3.1 Corpora . . . . .	5
3.2 RQ1. To what extent can we artificially generate program variants for WebAssembly? . . . . .	6
3.3 RQ2. To what extent are the generated variants dynamically different?	9
3.4 RQ3. To what extent the artificial variants exhibit different execu- tion times on Edge-Cloud platforms? . . . . .	11
3.5 Conclusions . . . . .	12
<b>4 Results</b>	<b>13</b>
4.1 RQ1. To what extent can we artificially generate program variants for WebAssembly? . . . . .	13
4.2 Answer to RQ1. . . . .	15
4.3 RQ2. To what extent are the generated variants dynamically different?	15
4.4 Answer to RQ2. . . . .	19

*CONTENTS*

vii

4.5	RQ3. To what extent the artificial variants exhibit different execution times on Edge-Cloud platforms? . . . . .	19
4.6	Answer to RQ3. . . . .	20
4.7	Conclusions . . . . .	21
<b>5</b>	<b>Conclusions</b>	<b>23</b>

# List of Figures

2.1	CROW workflow to generate program variants. CROW takes C/C++ source codes or LLVM bitcodes to look for code blocks that can be replaced by semantically equivalent code and generates program variants by combining them. . . . .	3
3.1	The program variants generation for RQ1. . . . .	7
3.2	Dynamic analysis for RQ2. . . . .	9
3.3	Multivariant binary creation and workflow for RQ3 answering. . . . .	11
4.1	Pairwise comparison of programs' population traces in logarithmic scale. Each vertical group of blue dots represents a programs' population. Each dot represents a comparison between two program execution traces according to Metric 2. . . . .	17
4.2	Execution time distributions for <code>Hilber_curve</code> program and its variants. Baseline execution time mean is highlighted with the magenta horizontal line. . . . .	18
4.3	Execution time distributions. Each subplot represents the quantile-quantile plot of the two distributions, original and multivariant binary. . . . .	20



# List of Tables

3.1	Corpora description. The table is composed by the name of the corpus, the number of modules, the number of functions, the lines of code range and the location of the corpus. . . . .	7
4.1	General program’s populations statistics. The table is composed by the name of the corpus, the number of functions, the number of succesfully diversified functions, the number of non-diversified functions and the cumulative number of variants. . . . .	14



# List of Acronyms

Wasm  
DTW

WebAssembly  
Dynamic Time Warping

